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A Redshift Survey of IRAS Galaxies

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ABSTRACT

We present results from a redshift survey of all 72 galaxies detected by IRAS in Band 3 at flux levels ≥ 2 Jy, and lying in the region $8^h < \alpha < 17^h$, $23.5° < \delta < 32.5°$. The 60 μm luminosities of these galaxies range from 1.4×10^8 $L_\odot$ to 5.0×10^{11} $L_\odot$. The luminosity function at the high luminosity end is proportional to L^{-2}, however, we observe a flattening at the low luminosity end indicating that a single power law is not a good description of the entire luminosity function. Only three galaxies in our sample have emission line spectra indicative of AGN's, suggesting that, at least in nearby galaxies, unobscured nuclear activity is not a strong contributor to the far-infrared flux. Comparisons between the selected IRAS galaxies and an optically complete sample taken from the CfA redshift survey show that they are drawn from different parent populations. The absolute blue luminosities of IRAS galaxies are more narrowly distributed than those optically selected, in the sense that the IRAS sample includes few galaxies of low absolute blue luminosity. We also find that the space distributions of the two samples differ: the density enhancement of IRAS galaxies is only ~1/3 that of the optically selected galaxies in the core of the Coma cluster.

1. Introduction

The study of IRAS galaxy source counts is important because IRAS offers the first all-sky survey sufficiently sensitive to detect galaxies, but relatively insensitive to surface brightness gradients. To interpret these source counts in terms of the space distribution of IR-bright galaxies, it is necessary to know their infrared luminosity distribution. Towards this end, we have exploited and extended the deep redshift survey carried out by de Lapparent, Geller, and Huchra (1986) over a selected "slice" of the sky (the CfA survey).

2. Materials and Methods

Our sample includes all sources listed in the IRAS Point Source Catalog or the Small Extended Source Catalog above a flux limit of 2 Jy at 60 microns, and lying within the 1072 square degree region between $8^h < \alpha < 17^h$, $23.5° < \delta < 32.5°$. Eighty-six sources met the selection criteria. Optical identifications were made on the basis of positional proximity. Thirteen are stars, one is a planetary nebula, and 72 are galaxies. Twenty-two of the galaxies in our sample were found to occur in groups of two or more. In cases where more than one galaxy falls in the quoted Point Source Catalog error box, the IRAS source was associated with the brightest galaxy.

Spectra with a resolution of 6-7 Å covering 4600-7200 Å were obtained at the F.L.Whipple 1.5m telescope and at the MMT. Several galaxies were observed in the confused cases; all of our pairs appear to be physically associated, i.e. at the same redshift. Redshifts

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and equivalent widths of the Hα, Hβ, [OIII] λ5007, [OI] λ6300, and [NII] λ6585 lines were determined from these spectra. For galaxies brighter than $m_B \sim 15.7$, blue magnitudes were taken from the Zwicky Catalog. For fainter galaxies, eye estimates were made.

3. The 60 μm Luminosity Function

We define the 60 micron luminosity as the energy in the band:

$$L = 4\pi r^2 F_\nu \Delta\nu$$

where F_ν is the IRAS flux density and $\Delta\nu$ is the bandwidth ($= 3.75 \times 10^{12}$ Hz; Neugebauer *et al.* 1984). We calculate r by assuming $H_o = 100$ km/s/Mpc^3 and correcting for 300 km/s galactic rotation and deviation from the Hubble flow due to infall towards the Virgo cluster of 300 km/s as in Huchra and Geller (1982).

The distribution of luminosities and the luminosity function

$$\Phi(L) = \frac{4\pi}{\Omega}\frac{1}{\Delta L_i}\sum_j \frac{1}{V_j}$$

are shown in Figure 1. Here $\Omega/4\pi$ is the fraction of the sky covered by this survey, ΔL_i is the bin width, and V_j is the volume of the universe out to which a galaxy of luminosity L is observed at our flux limit. Uncertainties in the luminosity function were calculated assuming Poisson distribution errors, proportional to $\sqrt{N}$. Thus we have ignored errors in the luminosities due to uncertainties in the infrared fluxes and deviations from Hubble flow which are not completely eliminated by our corrections for Virgocentric motion. The data from Soifer *et al.* (1986), corrected to our units, are shown for comparison.

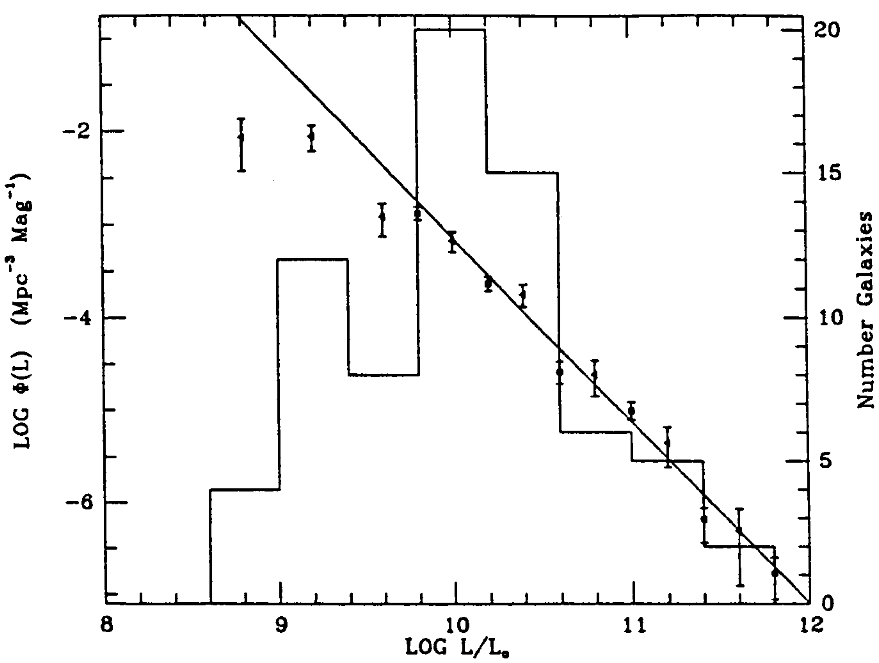

Figure 1. The 60 micron luminosity function. The triangles are the points derived from our sample; the squares are from Soifer *et al.* (1986). The units on $\phi(L)$ are Mpc^{-3}mag^{-1}, and the error bars are proportional to $\sqrt{N}$. The histogram is the number count of galaxies in each luminosity bin (right axis).

To describe this data in a useful analytical form, we have tried both a Schechter (1976) function and a single power law. Neither yielded a good fit; at high luminosities the density lies below that expected for a Schechter function, and at low luminosities the density is less than expected for a single power law. However, the apparent flattening of the luminosity function at the low luminosity end may be due to incompleteness due to low surface brightness galaxies larger than 2 arcminutes. The line shown is a best fit power law to our data above $10^{10} L_{\odot}$ of $\phi(L) = 3.5 \times 10^{16} (L/L_{\odot})^{-2}$ $Mpc^{-3} mag^{-1}$. The slope is confined to a range of −1.7 to −2.1 with a 68% confidence. This fit is consistent with the fit derived by Soifer *et al.* (1986) from a brighter sample.

4. Comparison with Optical Sample

Figure 2 shows the absolute magnitude distribution of our infrared-selected sample, the Center for Astrophysics blue-selected sample from Huchra *et al.* (1983), and the CfA spirals. This figure clearly shows that the galaxies in our sample have a narrower range of absolute blue magnitude than those of an optically selected sample. The mean for this sample is −19.2 with a standard deviation of only 0.8. We find that IRAS undersamples galaxies of low absolute blue luminosity. There also appears to be a deficiency of galaxies of high blue luminosity. A Kolmogorov-Smirnov test gives an 95% probability that the two samples are not derived from the same parent population.

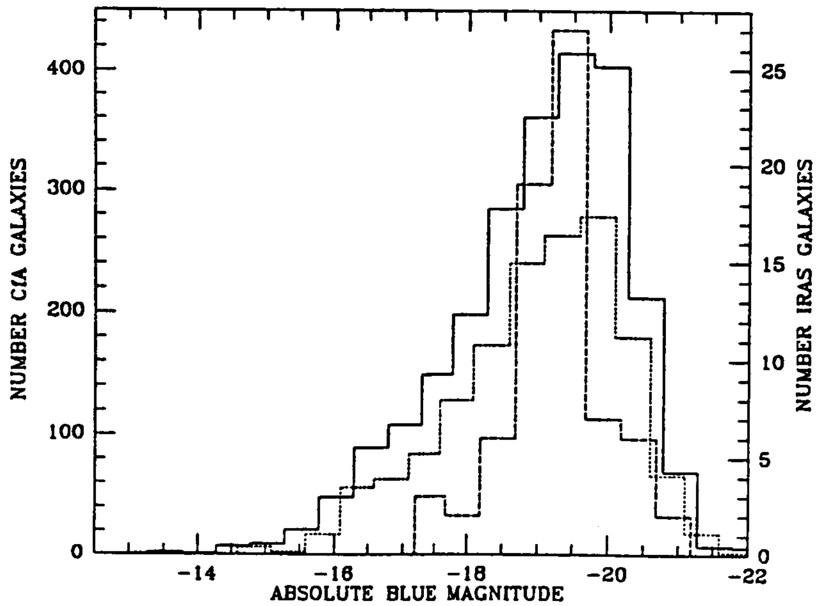

Figure 2. The absolute magnitude distribution of the IRAS sample (dashed histogram), the CfA blue-selected sample (solid histogram), and the CfA spirals (dotted histogram).

We also see a difference in the blue magnitude distributions of IRAS galaxies and CfA spirals. A Kolmogorov-Smirnov test gives a 99% probability that the IRAS galaxies are not drawn from the same parent population as the CfA spiral galaxies. However, a Mann-Whitney test shows that there is only a 1 sigma difference in the medians. We can thus conclude that the distributions are different in that the IRAS sample excludes galaxies of low blue luminosity, and therefore has a narrower range in blue luminosity.

A possible explanation is low metallicity in low mass galaxies. Metallicity has been shown to be correlated with blue luminosity, in ellipticals (Faber 1973) and in spirals (Bothun *et al.* 1984). If dust content is a function of metallicity, then we would expect the observed difference in the blue magnitude distributions of IRAS galaxies and CfA spirals. It is important to note that the blue luminosity is enhanced by recent star formation; M/L of the IRAS galaxies may differ from that of the CfA galaxies. It is thus not possible to conclude that only more massive galaxies are detected by IRAS. It is also important to emphasize that the infrared luminosity is both a function of the dust content and of the proximity of the dust to the heating sources. It may simply be the case that galaxies of low blue luminosity have a lower percentage of HII regions embedded in molecular clouds.

Two galaxies in this sample are Seyfert 2 galaxies; one is a Seyfert 1. The percentage of active galaxies in this infrared selected sample is thus not significantly different from that of the CfA sample. We find no correlation between [OIII]/Hβ and the infrared excess L_{60}/L_B, again indicating that unobscured nuclear activity is not a strong contributor to the 60 μm flux in this sample.

Comparing the space distribution of our sample with that of the CfA sample, we find that the IRAS galaxies follow the cellular pattern of galaxies observed by de Lapparent, Geller, and Huchra (1986), however, a density enhancement in the core of Coma the size of the CfA density enhancement is not observed. The IR density/B density ratio in Coma is ~1/3 that of the mean of the remainder of our box. This is most easily explained by the fact that IRAS preferentially detects spirals (Wolstencroft *et al.* 1985), while Coma is dominated by E's and S0's (Dressler 1980). We therefore expect that IRAS is systematically underestimating the mass in rich clusters; this introduces errors into the gravitational dipole moment derived by Yahil *et al.* (1985) and Meiksen and Davis (1986).

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REFERENCES

Bothun, G.D., Romanishin, W., Strom, S.E., and Strom, K.M. 1984, *A.J.*, **89**, 1300.
de Lapparent, V., Geller, M.J., and Huchra, J.P. 1986, *Ap.J.(Letters)*, **302**, L1.
Dressler, A., 1980, *Ap.J.Supp.*, **42**, 565.
Faber, S.M. 1973, *Ap.J.*, **179**, 731.
Huchra, J.P., Davis, M., Latham, D., Tonry, J. 1983, *Ap.J.Supp.*, **52**, 89.
Huchra, J.P., and Geller, M.J. 1982, *Ap.J.*, **257**, 423.
Meiksin, A., and Davis, M., 1986, *A.J.*, **91**, 191.
Neugebauer, G., *et al.* 1984, *Ap.J.(Letters)*, **278**, L1.
Schechter, P. 1976, *Ap.J.*, **203**, 297.
Soifer, B.T., *et al.* 1986, *Ap.J. (Letters)*, **303**, L41.
Wolstencroft, R.D., *et al.*, 1986, in: Light on Dark Matter, F.P. Israel, ed., Reidel, p.425.
Yahil, A., Walker, D., Rowan-Robinson, M. 1986, *Ap. J. (Letters)*, **301**, L1.